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Biogas energy use in Nigeria: current status, future prospects and policy implications

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Abstract

Industrial revolution brought coal, a fossil fuel, to the forefront of the global energy scene. This was later overtaken by another fossil fuel, crude oil; and natural gas is trying fast to take over the dominant role in the world energy supply mix. The increasing world-wide awareness and concern about the environmental impacts of fossil fuels coupled with the oil price shocks of the early 1970s and late 1980s, and likely future price hikes, have lent enormous weight to a switch to renewable energy sources. This paper therefore looks at biogas (renewable) energy use in Nigeria, a country which is fossil fuels rich and an oil exporting nation. In order to contain the uncertainty usually associated with structural transformation of the economy typical of a developing country like Nigeria, a three scenario analysis has been adopted to examine the future prospects of biogas in the country. While a generated energy from biogas would range between $5.0–171.0\times10^{12}$ J in the period 2000–2030 under a moderate ambitious biogas technology programme, some constraints may hinder this realization. These include economic, technical and socio–cultural constraints. Recommendations to overcome these constraints and make biogas technology penetrate even more than already projected into the rural communities and poor urban households have been suggested. Part of the envisaged benefits of biogas use to the national economy includes the avoidable CO_2 emissions. If biogas displaces kerosene, at least between 357–60,952 tons of CO_2 per annum would be avoided.

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1. Introduction

Since the 1970s oil price shocks, increased attention has been paid to the development of technologies using new and renewable sources of energy like solar, wind, hydropower, and biomass. Biomass fuels (wood, crop residues, dung, etc.) are used daily in about half the world's households as energy for cooking and/or heating. In the developing countries, these sources are more important because many of these nations don't have the scarce conventional energy sources such as crude oil, natural gas, and coal. The new and renewable energy resource systems offer attractive prospects because they are pollution free, unlimited, and cheap. They also preserve ecosystems and retard degradation of the environment. In addition, these energy resources can be developed extraordinarily rapidly as shown by the experience with wood fuel in the USA, small hydropower and biogas in the Peoples Republic of China (PRC), and energy crops in Brazil [1]. Government commitments to the development and promotion of renewable energy sources have been instrumental in promoting an ambitious alcohol fuel program in Brazil, geothermal and wood energy programs in the Philippines [2] and biogas programs in the Peoples Republic of China (PRC) and India.

China and India are pioneers in the development and application of anaerobic technologies for the production of fuel gas and waste treatment. With the introduction of household-size biogas digester technology in the early 1950s, China has followed a consistent program of development, technical support, and assisted technology diffusion, with the result that biogas digester technology has been widely adopted to supply fuel for rural household lighting and cooking [3]. At least about 6.5 million and 1.8 million biogas plants are already in use in the PRC and India, implying that at least about 3.8% and 0.7% of the populations of the PRC and India, respectively, use biogas [1,4].

Biogas energy use is spreading across the developing nations of the world. Various kinds of biogas plants—the Indian, Taiwanese, Chinese, and Philippine plants are already in use. In Africa, biogas producing units exist in almost all the sub-regions in the continent. These range from small/medium digesters with gas production capacity of less than 100 cubic metres to larger digesters with gas production capacity greater than 100 cubic metres. Table 1 gives a list of the African countries with biogas production units as at 1993. The two common types of digester design in use in the sub-Saharan Africa (SSA) are the Indian digester technology which involves a floating steel dome and the Chinese type which involves a fixed concrete dome. It has been observed that biogas technology has had very little success in SSA except in Tanzania and Burundi where some hundreds of plants have been constructed and are being used [6].

While biogas plants are not yet familiar in the Nigerian energy market, some substantial work has been done and work is still in progress on it. For instance, the Usman Danfodiyo University, Sokoto, has designed a plant that can produce 425 litres of biogas per day which could be sufficient to cook meals for one person [7]. Similarly, an engineering design and economic evaluation of a family-sized plant has been carried out at the Technology Planning and Development Unit, Obafemi

Table 1
Countries with biogas producing units in Africa as at 1993 (from [5])

Country	Number of small/medium digesters (100 m^3)	Number of large digesters (>100 m^3)	Region
Botswana	Several	1	Southern Africa
Burkina Faso	>20	–	West Africa
Burundi	>136	–	East Africa
Egypt	Several	>1	North Africa
Ethiopia	Several	–	East Africa
Ghana	Several	–	West Africa
Cote D'Ivoire	Several	1	West Africa
Kenya	>140	–	East Africa
Lesotho	Few	–	Southern Africa
Malawi	–	1	Southern Africa
Morocco	Several	–	North Africa
Rwanda	Several	–	East Africa
Senegal	Several	–	West Africa
Sudan	Several	–	North Africa
South Africa	Several	Several	Southern Africa
Swaziland	Several	–	Southern Africa
Tanzania	>600	–	East Africa
Tunisia	>40	–	North Africa
Uganda	Few	–	East Africa
Zimbabwe	>100	–	Southern Africa

Awolowo University, Ile-Ife [8]. In addition, various research work on the science, technology and policy aspects of biogas production has been carried out by various scientists in the country [9–15]. In the light of these, the focus of this paper is on the present status and the future prospects of biogas energy use in the country. In doing this, the paper gives the current energy use trend in the Nigerian economy, the various resources available for biogas production in the country, the current use and likely future utilization trend of biogas in the national economy, the benefits of its use to the economy, possible barriers to its diffusion into the national energy market, and suggested recommendations to overcome the observed constraints.

2. Energy use trend in the national economy

Nigeria is an energy resource rich country blessed with both fossil fuels such as crude oil, natural gas, coal, and renewable energy resources like solar, wind, biomass, biogas, etc. Similarly, Nigeria is also human resource rich with a total population of 88.5 million by the 1991 population census, and an annual population growth rate of about 2.8%. It will therefore be logical to conclude that the abundant energy resources should sufficiently sustain the teeming population. However, this is not so. The national energy use trend reveals a dichotomy between the urban and the

rural households. This is due to the types of energy forms consumed in the country, namely commercial energy (petroleum products, natural gas, coal, and electricity), and non-commercial or traditional energy (mostly fuelwood and other biomass). For instance, out of the total energy consumed in 1990, commercial energy accounted for about one-third, while the remaining share went to traditional fuel. Fig. 1 which shows a distribution of energy consumption in the country in 1991 gives a more graphical illustration of this dichotomy in commercial and traditional energy consumption patterns in the country.

Nigeria's urban population in the year 2030 is estimated to be between 46–54% of the total population which is also estimated to be about 250 million. This is an indication that a large population of the citizenry will still be living in the rural areas. Already the country is faced with an energy crisis—both commercial and traditional energy resources. The petroleum products have been in acute shortage in the urban areas since the dawn of the 1990s, although less acute incidents have been witnessed since 1975. This has resulted in untold hardship to the economy and the entire citizenry. Without doubt, the rural populace has had its own share of energy crises. Apart from insecurity of supply of petroleum products to areas which are at least lucky to have supplies however erratic, the recurrent national energy crisis has had a more deepening impact on the rural areas. Although the poor urban households generally depend on biomass for their energy needs, the rural households take the lion's share of the total biomass use in the country. Currently, there is increasing scarcity of the more desirable types of wood which has led to greater use of lower quality wood. The resultant effect of this is the need for a greater quantity of wood to produce similar energy supplies to previously [16]. In addition, the gathering time of fuelwood and other biomass has increased considerably and people have had to walk long distances before finding sufficient quantities to gather.

It has also been observed that in West Africa the most populous countries produced and consumed the greatest amount of fuelwood between the period 1980–1992. For instance, the three most populous countries in West Africa—Nigeria, Ghana and Ivory Coast—produced a total of 117 million m^3 of fuelwood which represented 75.1% of the total quantity of fuelwood produced in the sub-region in 1992 [17]. As expected Nigeria, which is the most populous country not only in the West African sub-region but also in all Africa, produced 96.8 million m^3 of wood which

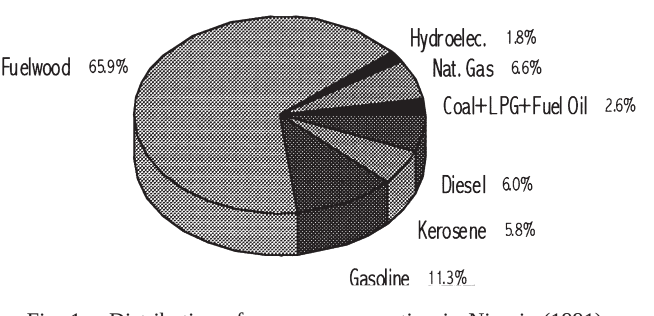

Fig. 1. Distribution of energy consumption in Nigeria (1991).

represented 62.2% of the total fuelwood production in West Africa in 1992 [18]. To further buttress this point, a World Bank study [19] has revealed that fuelwood deficit has already gained entry into Nigeria's energy mix, while another study [20] also confirms the World Bank study although it says the fuelwood deficit will come in as from the year 2000. The implication of these is that with the expected increasing population, it will become harder and harder for the biomass, especially fuelwood, dependent teeming population to meet its energy requirements. This has its own attendant socio–economic impacts which include less light, less warmth, less cooked food and of course health problems. Furthermore, some environmental problems have been observed to be associated with intensive and inefficient use of wood for fuel. These include desertification, deforestation, and devegetation. Deforestation and devegetation that result from fuelwood use and other activities imply increased efforts to mitigate greenhouse gases emission. This is because plants which served as sinks for CO_2 have been lost to deforestation and devegetation, and the burning of existing wood stocks releases substantial amounts of greenhouse gases, particularly CO_2, into the atmosphere.

3. Biogas energy resources

Biogas is produced by the biodegradation of organic material under anaerobic conditions. That is, it arises from the bacterial decomposition of organic matter in the absence of air. Some of the biogas producing materials (substrates) range from animal dung to household, agricultural and industrial wastes (see Table 2). It has been observed that generally there is an improvement in the quantity of gas produced from a particular waste when it is mixed with other waste [21]. Table 3 gives the average gas production for various wastes showing an observed percentage increase for the mixture of wastes over that of the average of the two wastes taken separately.

In Nigeria, identified feedstock substrate for an economically feasible biogas programme includes water lettuce, water hyacinth, dung, cassava leaves, urban refuse, solid (including industrial) waste, agricultural residues and sewage [22]. Tables 4 and 5 present the various agricultural and livestock resources and their associated residues as the potential substrates for biogas production in the country. It has been estimated that Nigeria produces about 227,500 tons of fresh animal wastes daily. Since 1 kilogram (kg) of fresh animal wastes produces about 0.03 m^3 gas, then Nigeria can produce about 6.8 million m^3 of biogas every day. In addition to all these, 20 kg of municipal solid wastes (MSW) per capita [24] has been estimated to be generated in the country annually. By the 1991 census figure of 88.5 million inhabitants, the total generated MSW will be at least 1.77 million tonnes every year. With increasing urbanisation and industrialisation, the annual MSW generated will continue to increase [22]. Biogas production may therefore be a profitable means of reducing or even eliminating the menace and nuisance of urban wastes in many cities by recycling them.

Table 2
Available biogas substrates

	Type	Source
A.	Animal dung	Cow
		Buffalo
		Chicken
		Pig
		Duck
B.	Household wastes	Kitchen wastes
		Night soil
C.	Crop residues (air dry)	Corn stalk
		Rice straw
		Corn cobs
		Peanut shells
		Baggage
		Grass trimmings
D.	Industrial wastes	Breweries
		Wineries
		Bakeries
		Confectioneries
		Distilleries
		Tea processing factories
		Noodle factories
		Other industrial organic waste water

Table 3
Increase in gas yields obtained with mixtures of wastes at a retention time of 40 days (from [21])

Wastes	Gas Production (m^3/kg)	% Volume
Cattle	0.380	
Pig	0.569	
Poultry	0.617	
Sewage	0.265	
Weeds	0.277	7
Cattle+Pig (50:50)	0.510	6
Cattle+Sewage (50:50)	0.407	16
Cattle+Weeds (50:50)	0.363	5
Poultry+Sewage (50:50)	0.413	1
Poultry+Weeds (50:50)	0.495	1
Sewage+Weeds (50:50)	0.387	39

4. Current and future utilization

Presently, biogas is not in the national energy equation. However this is not to say that already a few units of biogas digesters are not in use both in the urban and rural segments of the country for various activities. In a recently concluded study,

Table 4
Agricultural resources and residues in Nigeria for 1992 (from [23])

Resources	Production (10^3 ton)	Residue (10^3 ton)	GJ
Industrial wood+fuel wood+charcoal	214250	85700	805580
Cereals	12403	16124	207540
Roots and tubers	41602	16641	106502
Sugarcane	–	–	3.097
Cotton	276	358.8	6387
Coconuts	135	175.5	2246
Coffee (Green)	3	3.9	50

Table 5
Livestock resources and residues in Nigeria in 1992 (from [23])

Resources	Stock (10^3 head)	Residue (GJ)
Cattle	15700	32342
Sheep and goats	37500	15375

a 6.0 m^3 family-sized biogas digester will generate 2.7 m^3 of biogas per day to satisfy the cooking requirement of a household of an average size of 9.0 persons. This project has been estimated to have an initial investment cost of N41,088 (about US$500), annual expenditure of N5,909 (about US $70) and an annual benefit of N13,347 (about US$160) [8]. Although the financial analysis of this project declares it to have a good economic potential, its high first cost may make it inaccessible to the majority of its intended users—the poor urban and rural households. Unless some measures are adopted either to bring down its capital cost or economically aid its intended users, biogas use may turn out to be another fuel for the high-income households and thereby defeat the objective of making it penetrate into the low-income households. With this background information, and in order to project biogas use into the future, a three scenario analysis of its market penetration has been adopted. Assumptions underlying this scenario analysis are:

- population growth
- household income
- government intervention
- substrate availability.

Using the National Population Commission 1991 census and population annual growth rate, and an average household size of 9 persons, Table 6 gives the population projections and the associated total number of households. Based on the fact that the population and associated number of households projections already give a cumu-

Table 6
Total population and corresponding number of households projections

	1995	2000	2005	2010	2015	2020	2025	2030
Population 10^6	98.84	113.47	130.27	149.56	171.70	197.13	226.31	259.82
No. of Households 10^6	10.98	12.61	14.47	16.62	19.08	21.90	25.15	28.87

lative growth trend, the adopted three scenarios are based on the following assumptions:

- Low Biogas Growth Scenario=0.1% of the households per annum adopt biogas digesters
- Moderate Biogas Growth Scenario=0.5% of the households per annum adopt biogas digesters
- High Biogas Growth Scenarios=1.5% of the households per annum adopt biogas digesters.

This study further assumes that the programme to intensively penetrate the Nigerian energy market with biogas digesters takes off finally in the year 2000. Then the number of biogas digesters in the country between 2000 and 2030 based on the three scenarios above are as given by Table 7. This table implies that within the next three decades it is possible to have between 144,350–2,165,250 family-sized biogas digesters in the national energy supply mix. At the 1998 cost estimate of a family sized digester [8], the aggregate financial implications of these projections are investment cost, between N5.931×10^9 (about US\$$72.175\times10^6$) and N$88.966\times10^9$ (about US\$$1.083\times10^9$); annual operating costs between N0.853×10^9 (about US\$$10.10^5\times10^6$) and N$12.794\times10^9$ (about US\$$0.152\times10^9$). Based on a study that a 6.0 m^3 family-sized biogas digester will generate 2.7 m^3 of biogas (about 79.11 MJ), the likely trend of energy that can be obtained from the projected number of family-sized biogas digesters in the country in the future is depicted by Fig. 2.

5. Benefits of biogas energy use

Biogas is suitable for practically all the various fuel requirements in the household, agriculture and industrial sectors. For instance, domestically, it can be used for cooking, lighting, water heating, running refrigerators, water pumps and electric generators. Agriculturally, it can be used on farms for drying crops, pumping water for irrigation and other purposes. In industry, it can be used in small-scale industrial operations for direct heating applications such as in scalding tanks, drying rooms and in the running of internal combustion engines for shaft power needs. Apart from producing a valuable fuel, biogas production also helps in promoting sanitation by turning wastes that are potential public nuisances and liabilities to public health and in controlling environmental pollution through the conversion of organic wastes into useful organic fertiliser and feed material. Since the fertiliser produced is digested sludge which contains all the nutrients present in the original waste materials, as well as in a finely processed state that is ready to be utilised by crops, it enhances good soil structure. Furthermore, it also helps in controlling environmental pollution by displacing kerosene, charcoal, fuelwood, diesel and thereby reducing greenhouse gases emissions. For instance, if there is a fuel switch from kerosene to biogas, at least between 356.5 and 60,961.5 tons of CO_2 emissions into the atmosphere annually would be avoided with the projected biogas use in this study. Similarly, by turning

Table 7
Total number of digesters projected for the country for the period 2000–2030

Projected biogas digesters	2000	20005	2010	2015	2020	2025	2030
Low growth scenario	63,050	72,350	83,100	95,400	109,500	125,750	144,350
Moderate growth scenario	315,250	361,750	415,500	477,000	547,500	628,750	721,750
High growth scenario	945,750	1,085,250	1,246,500	1,431,000	1,642,500	1,886,250	2,165,250

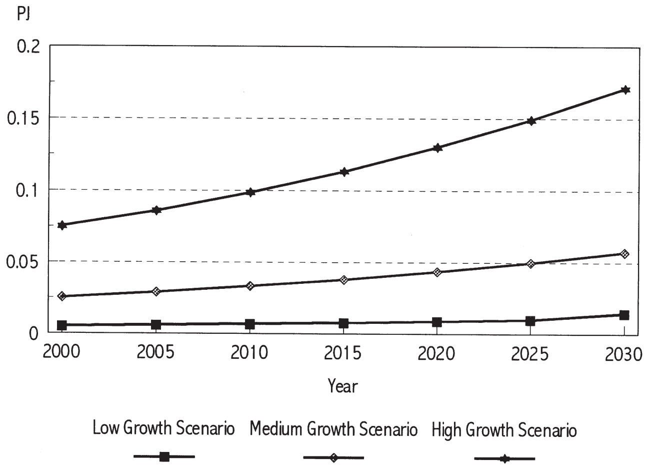

Fig. 2. Energy consumption trend from projected family-sized biogas digesters in Nigeria for the period 2000–2030.

solid wastes into biogas there is a reduction in the release of methane and other gases that emanate from various refuse dumps into the atmosphere.

Biogas has a higher heating value than producer gas and coal gas which implies increased services. Also, unlike producer gas and coal gas which contain high levels of toxic carbon monoxide, biogas has no danger of health hazards or offensive odour. It burns with a clean bluish, sootless flame thereby making it non-messy to cooking utensils and kitchens. Biogas plant is simple and easy to construct from readily available materials and its operation does not require special skills. Biogas technology enhances energy supply decentralization, for instance rural communities having difficulties or no access to commercial fuels can produce biogas to meet their fuel needs, thereby increasing reliability of fuel supply and enhancing energy security to the rural areas. Consequently, this will help raise the standard of living of the rural populace. Construction of biogas plants can help to create new jobs, especially in the energy sector, and thereby decrease the unemployment rate in the country and stimulate the rural economy.

6. Barriers to the implementation of a biogas technology programme

Barriers to the popularization of biogas technology in the country include technical, economic and socio–cultural constraints.

6.1. Economic

Several factors will influence the decision of a family to adopt biogas technology to meet its domestic fuel requirements. The first on the list is the first cost (or initial investment cost). The average Nigerian rural household is essentially dependent on

farming for its subsistence and hence is not economically buoyant enough to afford the capital investment in a biogas plant given earlier on. At the present investment and annual running costs, owning a biogas plant resembles the acquisition of a prestigious item which can only be financed from excess funds. Biogas plants can therefore be acquired only by the relatively rich farmers. Even in the urban setting, the same observation is applicable. Hence, a family-sized biogas plant may not be economically feasible unless it is used for productive purposes like irrigation, motive power and other commercial purposes in addition to providing fuel for domestic cooking.

A biogas plant requires a considerable amount of residential space. For a biogas plant to operate economically, the kitchen, animal shed for dung generation, slurry compost pit and the plant itself must all be close together. If not, a very long connecting pipe is needed, this may reduce gas pressure at the user's end [25,26]. However, in Haryana in India, biogas plants have been adopted by farmers with residential areas ranging from 125–785 square metres which provide sufficient space for the biogas plants to run successfully [1]. In Nigerian villages, houses are clustered together making it less feasible for family-sized-biogas plants. However, community biogas plants may be more feasible in this wise. Although Adeoti [8] already postulates that two heads of cattle per household per day will be adequate to provide the necessary substrate needed for the daily required gas production from a family-sized plant, even then, most Nigerian rural households do not own cattle, especially in the southern parts. Hence, cattle excrement dependent substrate for gas production from a biogas plant may not generally be feasible in the southern parts of the country where cattle rearing is not generally practised.

6.2. Technical

Production and utilization of biogas involve six major aspects which are:

- structural design and construction
- feedstock storage
- biomethanation process
- gas distribution and utilization
- recovery and utilisation of by-products
- economics and social factors

A breakdown of the first cost of the biogas plant designed by Adeoti [8] reveals that construction costs took about 65% while the rest is for facilities and installation, labour and land. The construction cost is high mainly because cement and steel are used in construction. In a related study [1], the cost of a family sized biogas plant in India was between 5–10 times higher than a similar Chinese plant which was even about 2–4 times bigger in capacity. This is because while the Indian digester was constructed with bricks and industrially advanced materials which were mostly unavailable locally, the Chinese one was constructed with locally available cement, stones, and a mixture of quicklime, sand and clay and no industrially advanced

material was used. In order to support and achieve a viable biogas programme in the country, Nigeria may have to follow in the steps of the Peoples Republic of China (PRC), that is, the type of design and materials for building a biogas plant should depend on the raw materials available in the locality. This will not only reduce the investment cost, it will also make the technology readily understood, adopted and maintained by the rural community. The more sophisticated technology can be reserved for the more affluent urban dwellers.

The temperature that is best suited for maximum biogas production is put at between 30–35°C [1]. Fermentation comes to a standstill when the internal temperature of the digester falls to 15°C. This has to be taken into consideration in some areas of the country especially in the southern part which has the tendency of having rainfall for several months in the year. While continuous operation of a plant depends on regular maintenance, maintenance is also dependent on the type of dome in use, whether it is a fixed or a floating dome. In India, the floating dome is primarily in use, and its maintenance requires daily semicircular rotation of the gas holder to break the scum, and annual painting of the steel gas holders is necessary to protect them against corrosion. The Chinese fixed dome requires a lighter maintenance but regular checking for leakage and gas regulation are essential. At present, there is no known biogas technology that has been in use for years, the performance of which has been properly assessed, monitored, and well perfected in the country. A technology learning curve still has to be undergone for Nigeria to finally come up with its own well perfected biogas technology.

6.3. *Socio–cultural*

Socio–cultural factors and inertia toward change, especially when it involves an unfamiliar (even though simple) technology, are potential barriers to the adoption and dissemination of biogas technology in the country. Even when households were informed in a household survey of the possibility of their not incurring additional expenses as a result of change of their cooking end use appliances to improved biofuel stoves and higher quality fuels, they still showed inertia to their adoption [16]. Possible reasons for inertia towards change may include fear of abandoning a well-known technology for the unknown (the issue of the age-long adage: “the devil that is known is better than the one unknown”), apprehension of the potential dangers inherent in the use of gas in case of any accident, the belief by the villagers using fuelwood to cook food that this practice gives better taste to food than using any other fuel type. Another socio–cultural factor is the low level of literacy in the villages which hinders effective flow of information that can enhance qualitative decision making.

Furthermore, if any biogas programme is to benefit from cow dung in Nigeria especially in the northern parts, the present nomadic system of rearing cattle must be changed so that the herdsmen and their cattle populations can be settled in permanent centres and feedlots where biogas plants can be installed or cow dung easily collected. Similarly, in the southern parts, the culture of allowing domestic animals (goats, hens, sheep, etc.) to wander about and litter the vicinity with their wastes,

especially in the rural areas, also must be changed if the biogas programme has to benefit from these animal dungs.

7. Recommendations and policy implications

Cost benefit analysis carried out on the family-sized biogas plant examined in this study already shows that high investment capital and maintenance cost are a major impediment to the adoption of biogas technology in the country. Considering the long term benefits of biogas technology both economically and environmentally, it may be necessary to introduce some financial incentives to promote its penetration and diffusion into the Nigerian energy market, especially in the rural areas. Such incentives may include soft loans, and subsidy (direct and indirect) on the technology. These have been the practice in India and China [1] and even in Denmark [27]. The Poverty Alleviation Programme (PAP), Community Banks, State and Local Governments, Commercial Banks and even private bodies could play a leading role on the issues of loans and subsidies. This may however be implemented under government regulations and policies. The economics of large-scale biogas plants, probably to serve communities, could also be investigated since they may have a much higher benefit–cost ratio compared to family-sized plants.

It is quite apparent from this study that well co-ordinated and appropriately funded research, development and demonstration (R,D&D) is essential to overcome the technical obstacles and be well abreast of development in biogas technology. Apart from the government quota, funding will also be needed from voluntary agencies locally and possibly internationally. Since biogas technology can really offset a lot of GHG emissions, it may go under the Clean Development Mechanism (CDM) as a Joint Implementation (JI) programme with the advanced countries to fund and use as $C0_2$ emissions trade-off. Major research areas will include development and use of local materials for the construction of biogas plants, improved fermentation process to obtain high biogas generation, design specifications for different plant sizes (plant construction techniques, slurry distribution, operational problems, gas appliances, etc.), development of effective and cheap appliances, applications of biogas and the sludge, socio–economic and administrative aspects of biogas use, socio–cultural factors that affect the adoption of biogas technology, and evaluation of performance of the technology.

In order to overcome the socio–cultural barriers, intensive educational and campaign programmes may have to be mounted to raise the awareness consciousness of the benefits of this technology. These may include publication and distribution of simple and well illustrated manuals, various propaganda mechanisms especially to the rural areas, organisation of training courses and seminars. In addition, the village level social organisations for implementing national programmes are rather weak to support effective popularisation of new technologies, and to overcome cultural inhibitions against their use. Hence, effective and intensive mobilisation of the rural communities, possibly through the rural extension services in the local government areas, should be pursued. It must be pointed out that an institutional framework needs

to be set up for the overall success of a biogas technology programme in the country. Such a body could be named the National Biogas Technology Development Programme (NBDP).

8. Conclusions

Although biogas technology is not familiar and popular in Nigeria, yet some scientific, engineering and economic based research work has been and is still being done on it. The projected quantity of family-sized biogas digesters into the future ranges between 144,350 and 2,165,250 units by the estimates of this study. While the projected future energy obtainable from these digesters ranges between 5.0–171.0 TJ, the associated aggregate financial commitment (first cost) lies in the range N5.93–88.97 billion (about US$72.16–1083.00 million), the annual operating cost is in the range N853–12,794 million (US$10.11–152.00 million). These costs exclude promotional and other miscellaneous expenses. Though the biogas technology programme is of immense benefit to the national economy, however, economic, technical and socio–cultural constraints are some of the envisaged barriers to the penetration of this technology in the Nigerian energy market. Some of the recommendations suggested to overcome them are the introduction of financial incentives such as soft loans and subsidies at the initial stage, well co-ordinated and adequately funded research, development, and demonstration (R,D&D), intensive educational and campaign programmes, and a well organised institutional framework for the overall success of a biogas technology programme in the country. In summary, the use of alternative technologies like biogas takes place in a complex environment in which a combination of factors such as technology, political will, economics, and personal motivation are all essential for its adoption and popularisation.

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